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Effect of different thermal environments on yield and yield attributes of different mustard genotypes under Chhattisgarh plain climatic conditions

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Abstract
The present investigation entitled "Effect of different thermal environments on Yield and yield attributes of different mustard genotypes under Chhattisgarh plain climatic conditions" was carried out at the research farm, I.G.K.V., Raipur during *rabi* season of 2015-2016. Dry matter accumulation was significantly maximum in crop sown on 25th November and thereafter the rate of dry matter accumulation declined due to delayed in sowing up to 15th December. Leaf area index was faster right from 25 DAS to 55 DAS with maximum values at 55 DAS in case of crop sown on 25th November as compared to delayed sown crop. Highest siliqua length was recorded in crop sown on 25th November with a maximum value of 6.23 cm in variety PT-303 and minimum in variety PT-30 (5.11 cm). The maximum number of seeds siliqua^{-1} was recorded in crop sown on 25th November in variety Pusa Mustard-26 (13.60) while the lowest were recorded in crop sown on 15th December in variety PT-30 (11.20) and 1000-seed weight was also recorded maximum in crop sown on 25th November in variety Pusa Mustard (6.01 g) while lowest was recorded from variety PT-30 (4.93 g) crop sown on 15th December. Highest stover and seed yield were recorded in crop sown on 25th November as compared to delayed sowings. Among the varieties, higher seed yield was recorded from Pusa mustard-26 in all thermal environments as compared to other varieties.

Keywords: Mustard, genotypes, thermal environments and yield attributes

Introduction
Oilseed crops are major constituent of Indian agriculture system after cereals and legumes. Oil extracted from oilseeds are important for human diet and is also source of raw materials for various industries such as paint, varnishes, lubricant, soap and perfume industries. Rapeseed-mustard is most valuable edible oilseed crop all around the world after the soybean and palm in term of area and production. Rapeseed and mustard contain 40-45% oil and 20-25% protein in seed. The oil is one of the most preferred cooking oils and is a good quality preservative, especially for the preparation of pickles. Its tender leaves are consumed as vegetables and seeds are used as condiments. Among the 53 rapeseed mustard growing countries Canada, China, India, Germany France, Australia, USA, etc. are the major growing countries. The worldwide annual production of rapeseed-mustard is 44.41 million tonnes of seed from an area of 27.24 million hectares. Canada is the leading producer followed by China and India (FAOSTAT, 2013) [2].

In Chhattisgarh, mustard is grown as rainfed crop after the rice and its sowing is dependent on harvesting of rice. Sowing of crop is often delayed due to growing of medium to late variety of rice by farmers. In Chhattisgarh mustard crop occupied an area of 0.67 Lakh ha with a production 0.54 Lakh tonnes and an average productivity of 807 Kg ha^{-1}. Sarguja is the leading district in the state with respect to area and production (Anonymous, 2012) [1]. During seed germination and maturity stage slightly high temperature is required. Optimum temperature is 25 °C. Rainfall, cloudiness and extreme cold and frost are harmful for the crop (Mukherjee *et al.*, 2014) [9]. Sowing of crop on different dates on different provides diverse thermal environmental condition. Early sowing and delayed sowing adversely affects the growth, development as well as yield of the crop but sowing on optimum time favours the crops to achieve maximum yield.

Material and Methods

The field experiment was carried out during the *rabi* season of 2015-2016, at the research cum instructional farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur. Raipur is located in south-eastern part of Chhattisgarh belongs to Chhattisgarh plain zone at latitudes, longitude and altitude of 21.16˚ N, 81.36˚E and 289.5 m above M.S.L. (Mean Sea Level) respectively. The climate of Raipur is sub-humid and often varies from moist sub-humid to semiarid. The mean annual rainfall is about 1250 mm, out of which 85 per cent rainfall is received during June to September. It is characterized by low rainfall and moderately low temperature during *rabi* season (October to February). Mustard is mainly grown during *rabi* season. Seasonal changes prevailing during the growing period of crop play an important role in the crop growth, which ultimately influences the yield of the crop.

1. Number of branches: Number of branches plant^{-1} (including primary and secondary) were counted from three places of 1 m^2 area in each plot fixed based on date of sowing for plant population observations. The average was worked out by dividing the summation by three.
2. Number of siliquae plant^{-1}: Number of siliquae plant^{-1} is an important character among the yield contributing characters. The number of siliquae from five randomly selected plants from each plot were counted separately and averaged out to obtained siliquae plant^{-1}.
3. Length of siliquae plant^{-1}: Twenty siliquae each from five randomly selected plants from each plot were taken and length was measured. Mean was calculated to record the length of siliqua plant^{-1}.
4. Number of seeds siliquae^{-1}: Twenty siliquae each from five randomly selected plants were taken, threshed separately and number of seeds was counted. Then mean was calculated to record the number of seeds siliqua^{-1}.
5. Seed and stalk yield: The crop from each net plot was harvested and tied in bundles after two days of sun-drying. The total produce (seed and stalk) was obtained by weighing the bundles through balance. The seed from each bundle was threshed out and after winnowing, the weight of cleaned seed was recorded. The stalk yield was obtained by subtracting the seed yield from the total bundle weight along with seed. Finally the seed and stalk yield was converted into Kg ha^{-1}.
6. 1000-Seed weight (Seed Index): A random sample was drawn from the seeds collected from each treatment. 1000-seeds were counted and weighed accurately with electronic balance and the same was recorded as 1000-seed weight.

Results and Discussion

Yield attributes and yield

1. Number of siliquae plant^{-1}

The data showing the influence of different thermal environments on number of siliquae plant^{-1} in mustard varieties are shown in table 1. A careful study of data indicates that significant difference in number of siliqaue plant^{-1} was found within varieties and date of sowing while non-significant difference was observed in interaction between date of sowing and varieties.

Table 1: Number of siliqua/plant of mustard varieties under different thermal environments

Varieties	Number of siliquae plant^{-1}			
	D1	D2	D3	Mean
PT-30	162.55	161.33	148.20	157.36
PT-303	164.82	166.02	148.85	159.89
Pusa Mustard-26	193.42	182.25	175.53	183.74
Mean	173.60	169.87	157.53	167.00
	D	V	D X V	
S.Em±	2.26	2.26	3.85	
CD	6.67	6.67	NS	
CV	4.0			

D1 25/11/2015, D2 05/12/2015, D3 15/12/2015

Among the different thermal environments number of siliquae plant^{-1} was observed highest in first thermal environment (173.60) as compared to second (169.87) and third thermal environments (157.53) in all the varieties which were significantly differed.

It is quite clear from the data that significantly maximum number of siliquae plant^{-1} were observed in variety Pusa Mustard-26 (183.74) followed by PT-303 (159.89) and PT-30 (157.36). However there was no significant difference between PT-30 and PT-303. This might be due to growth genetic makeup of individual variety and favorable temperature during vegetative and reproductive period which enhanced the number of primary and secondary branches at harvest. Hossen, (2005) [7] also reported that significant variation was found in number of siliquae per plant in different mustard varieties. Delayed sowing resulted in lower number branches.

2. Length of siliquae (cm)

The data showing the influence of different thermal environments on length of siliquae in mustard varieties are shown in table 2. Data revealed that the length of siliquae was higher in crop sown on 25th November (5.59 cm) as compared to delayed sowing *i.e.* 5th December (5.54 cm) and 15th December (5.35 cm). This might be due congenial environment for growth and development of crop which favors better length of siliquae.

Table 2: Length of siliqua (cm) of mustard varieties under different thermal environments

Varieties	Length of siliqua (cm)			
	D1	D2	D3	Mean
PT-30	5.32	5.38	5.11	5.27
PT-303	6.23	5.99	5.69	5.97
Pusa Mustard-26	5.23	5.26	5.25	5.25
Mean	5.59	5.54	5.35	5.50
	D	V	D X V	
S.Em±	0.63	0.63	0.10	
CD	0.18	0.18	NS	
CV	3.42			

D1 25/11/2015, D2 05/12/2015, D3 15/12/2015

It was observed that length of siliquae ranged from 5.11 cm to 6.23 cm in all the mustard varieties. The maximum average siliquae length of 5.97 cm was observed in PT-303 which was at par with the length recorded in PT-30 (5.27 cm) and Pusa Mustard -26 (5.25 cm). This might be due to genetic makeup of the variety.

3. Number of seeds siliqua^{-1}

The data showing the influence of thermal environments on number of seeds siliqua^{-1} of mustard varieties are shown in table 3. It can be seen from the table that maximum number of seeds siliqua^{-1} were observed in crop sown on 25th November (12.70) followed by 05th December (12.16) and 15th December (11.73) sowing. Among the mustard varieties, Pusa Mustard-26 recorded significantly highest number of seed siliquae^{-1} (13.02) followed by PT-303 (12.07) and PT-30 (11.47). These varieties produced higher seeds siliqua^{-1} and differed significantly among them, it is self-explanatory that these might be due to its different genetic makeup.

The interaction between thermal environment and varieties of mustard were found to be non-significant

Table 3: Number of seed siliquae^{-1} of mustard varieties under different thermal environments

Varieties	Number of seeds siliqua^{-1}			
	D1	**D2**	**D3**	**Mean**
PT-30	11.80	11.43	11.20	11.47
PT-303	12.70	11.87	11.67	12.07
Pusa Mustard-26	13.60	13.27	11.47	13.02
Mean	12.70	12.16	11.73	12.19
	D	V	D X V	
S.Em±	0.09	0.09	0.16	
CD	0.27	0.27	NS	
CV	4.00			

D1 25/11/2015, D2 05/12/2015, D3 15/12/2015

Interaction between mustard varieties and thermal environments was non-significant with respect to number of seed siliqua^{-1}. Variation in number seed might be due to genetic make of variety and increased temperature during seed filling stage. This result is in conformity with findings of Kasyap, (2008), Jahan and Zakaria, (1997) and Hossain *et al*., (1996) [3, 6] who also reported that siliqua length reduced due to delay in planting time.

4. 1000 seed weight (g)

The effect of different treatments on 1000-seed weight is shown in table 4. Among the dates of sowing, significant impact on the test weight (1000-seed weight) was observed. Maximum weight of 1000-seeds was observed in crop sown on 25th November sowing (5.61 g) whereas the minimum value of test weight was recorded in 15th December sowing (5.05 g). This might be due to delay in sowing of crop which shortened the reproductive phase of the crop resulted in lower seed weight. Similar finding was also reported by Bhuiyan *et al*., (2008) [4] who stated that 1000-seed weight reduced with the delayed planting time.

It was observed from the table that significantly maximum 1000 seed weight (5.70 g) was found in variety Pusa Mustard-26 and it was statistically at par with the result obtained from variety PT-303 (5.36 g), followed by PT-30 (5.00 g). Variety Pusa Mustard-26 required longer period and get sufficient time to complete their reproductive phase when sown on 25th November because of this 1000 grain weight was higher. This result is in agreement with the finding of Robertson *et al.*, (2004) [10] who described that weight of 1000-seeds varied from variety to variety and species to species due to delay in sowing.

Table 4: 1000 seed weight (g) of mustard varieties under different thermal environments

Varieties	1000 seed weight (g)			
	D1	**D2**	**D3**	**Mean**
PT-30	5.20	4.93	5.04	5.00
PT-303	5.62	5.42	5.06	5.36
Pusa Mustard-26	6.01	5.95	5.15	5.70
Mean	5.61	5.43	5.05	5.37
	D	V	D X V	
S.Em±	0.10	0.10	0.18	
CD	0.32	0.32	NS	
CV	5.80			

D1 25/11/2015, D2 05/12/2015, D3 15/12/2015

5. Stover yield (kg ha^{-1})

Data regarding the stover yield (kg ha^{-1}) of mustard varieties as influenced by thermal environments are shown in table 5. Varieties and thermal environments have significant effect on stalk yield.

Table 5: Stover yield (kg ha^{-1}) of mustard varieties under different thermal environments

Varieties	Stover yield (kg ha^{-1})			
	D1	**D2**	**D3**	**Mean**
PT-30	4461.31	4037.66	3125.51	3874.76
PT-303	4658.19	3881.60	3675.14	4071.64
PUSA Mustard-26	5754.72	5232.43	4881.05	5289.40
Mean	4958.07	4383.83	3893.90	4411.93
	D	V	D X V	
S.Em±	143.47	143.47	248.50	
CD	430.13	430.13	NS	
CV	9.76			

D1 25/11/2015, D2 05/12/2015, D3 15/12/2015

Different thermal environments significantly influenced the stover yield. Significant decline in stover yield was observed with delay in sowing of crop. The highest stover yield of 4958.07 kg ha^{-1} was obtained from sowing of crop on 25th November followed by stover yield of 4383.83 kg ha^{-1} by 05th December sowing and lowest yield of stover kg ha^{-1} recorded in 15th December sown crop. This might be due to delay in sowing which shortens the life cycle which lead to lower dry matter production and shortened vegetative period. This result is also supported by study of Bala *et al.*, (2011) [3] who reported that straw yield decreased with delay in sowing.

Effect of varieties and various thermal environments on stalk yield (kg ha^{-1}) of mustard are shown in table 4.13.The stover yield varied in different mustard varieties and different thermal environments. Pusa Mustard-26 produced the highest stover yield (5289.40 kg ha^{-1}) followed by PT-303 (4071.64 kgha^{-1}) whereas the lowest stover yield was obtained by variety PT-30 (3874.76 kg ha^{-1}). The highest stover yield might be due to genetic makeup and yield potential of varieties tested in present investigation.

6. Grain yield (kg ha^{-1})

Table 6: Grain yield (kg ha^{-1}) of mustard varieties under different thermal environments

Varieties	Grain yield (kg ha^{-1})			
	D1	D2	D3	Mean
PT-30	1144.38	1021.33	976.21	1047.31
PT-303	1179.93	1095.16	1028.17	1101.08
Pusa Mustard-26	1655.73	1439.70	1339.90	1478.44
Mean	1326.68	1185.40	1114.76	1208.94
	D	V	D X V	
S.Em±	28.93	28.93	7.18	
CD	86.72	86.72	NS	
CV	7.18			

D1 25/11/2015, D2 05/12/2015, D3 15/12/2015

Grain yield of mustard varieties tested by various treatments are presented in table 6. A critical examination of data revealed that grain yield of mustard varieties were affected significantly due to different thermal environments. The higher grain yield of mustard was obtained (1326.68 kg ha^{-1}) from sowing of crop on first thermal environment whereas lowest grain yield was obtained from third thermal environment. The sowing of crop on 25th November produced higher grain yield over the sowing of crop on 5th and 15th December. This might be due to overall congenial environment received by plants facilitating proper growth and development which turned in maximum grain yield. Many workers also reported Turhan *et al.*, (2010) [12], Tobe *et al.*, (2010) [11] and Islam *et al*. (2002) [5] that seed yield of mustard significantly decreased as sowing time was delayed.

Among the varieties, Pusa Mustard-26 produced higher grain yield (1478.44 kg ha^{-1}) followed by PT-303 (1101.08 kg ha^{-1}) and PT-30 (1047.31 kg ha^{-1}). The variation in yield in different varieties might be due to expression of their genetic makeup and response to growing environments under the agro-climatic zone. However the interaction between varieties and thermal environments had shown non-significant difference.

7. Harvest index

Table 7: Harvest index of different mustard varieties under different thermal environments

Variety	Harvest index (%)			
	D1	D2	D3	Mean
PT-30	31.28	30.15	29.28	30.238
PT-303	31.27	30.56	30.78	30.872
Pusa Mustard-26	34.03	31.60	32.78	32.803
Mean	32.20	30.77	30.95	31.30
	D	V	D X V	
S.Em+-	0.36	0.36	0.62	
CD	1.08	1.08	NS	
CV	3.47			

D1 25/11/2015, D2 05/12/2015, D3 15/12/2015

The effect of different treatments on harvest index is shown in table 4.15. Among the dates of sowing, maximum value of harvest index was observed in crop sowing on 25th November as compared to sowing of crop on 5th and 15th December. This might be due to high temperature under delayed sowing during seed filling stage which lowered economical yield. The results are agreed with finding of Robertson, (2005) [10] who reported reduction in harvest index in delayed sowing due to high temperature.

Among the varieties, higher value of harvest index was observed in Pusa Mustard-26 as compared to variety PT-303 and PT-30. This might be due to bold seeding character of variety Pusa Mustard-26.

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